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US 5141057 A **US 4062551 A**

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Other: **Online: WPI, EPODOC, JAPIO**

(54) Abstract Title: **Deploying a control line in a subterranean well**

(57) A control line 20 in a subterranean well 12 is deployed within a lower string 18 and outside an upper string 16. The control line 20 may transfer from the inside to the outside via a ported sub (38, figure 8) and may transmit either an electrical, hydraulic or optical signal. The control line may be used to measure a temperature profile along its length.

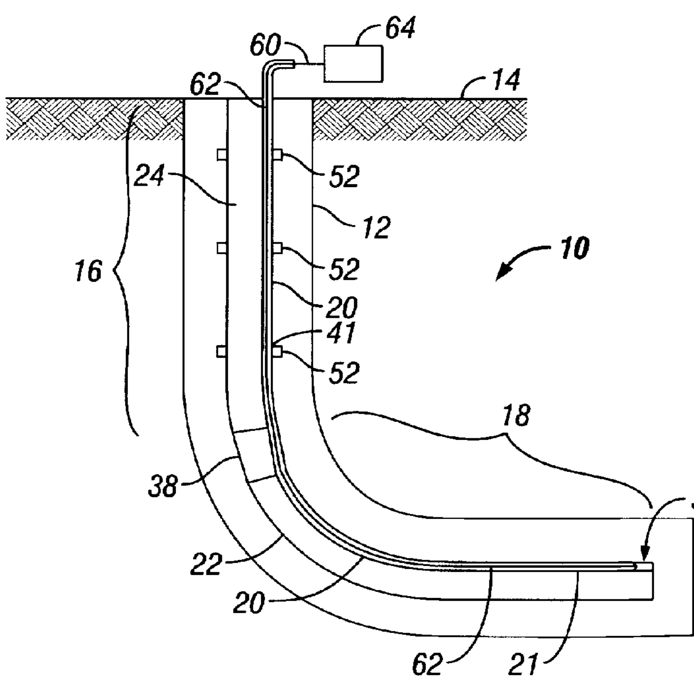

FIG. 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995 This print incorporates corrections made under Section 117(1) of the Patents Act 1977.

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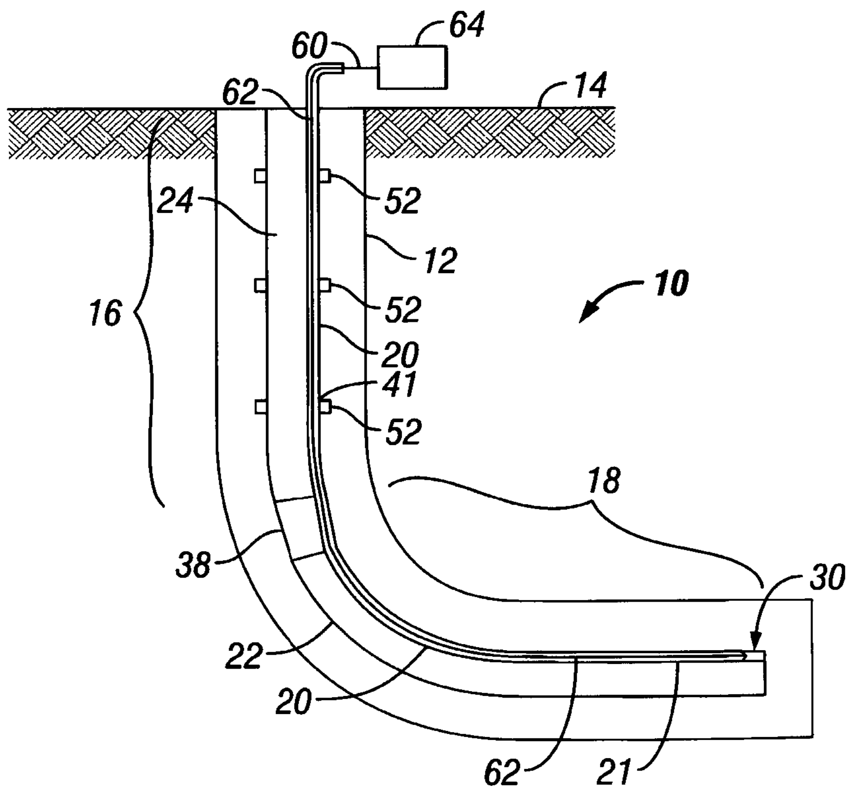
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FIG. 1

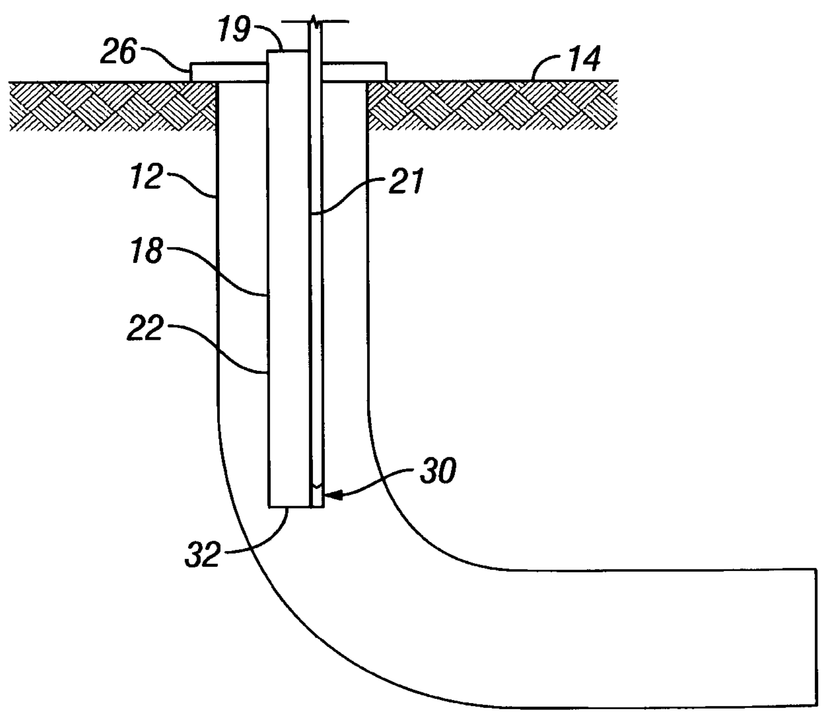
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FIG. 2

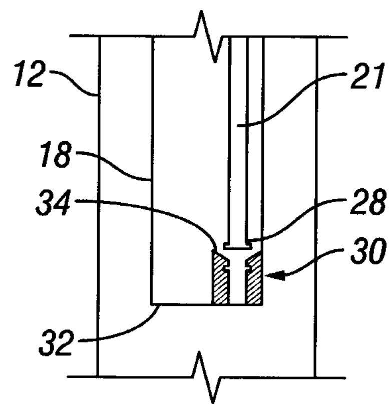

FIG. 3

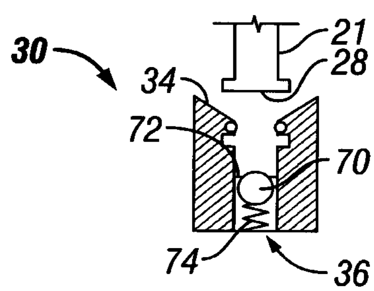

FIG. 4

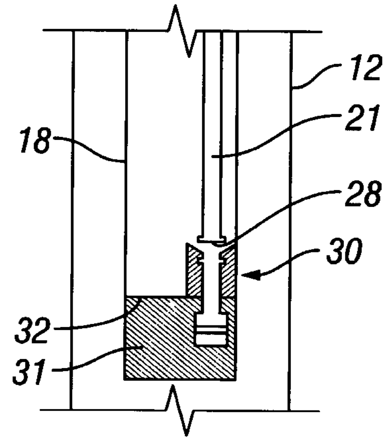

FIG. 5

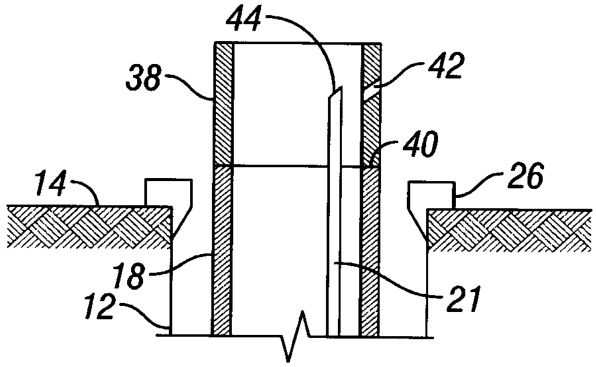

FIG. 6

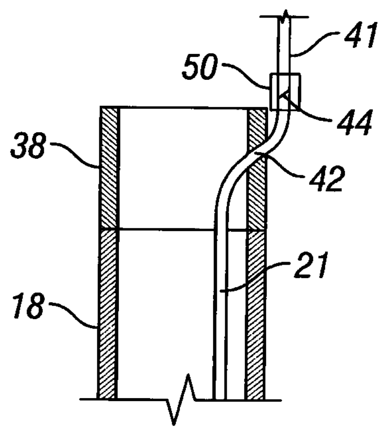

FIG. 7

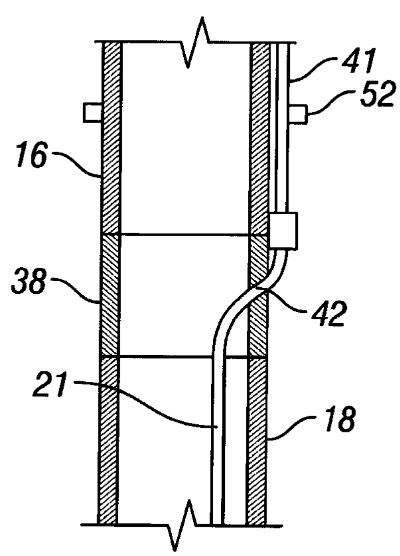

FIG. 8

20 41 04

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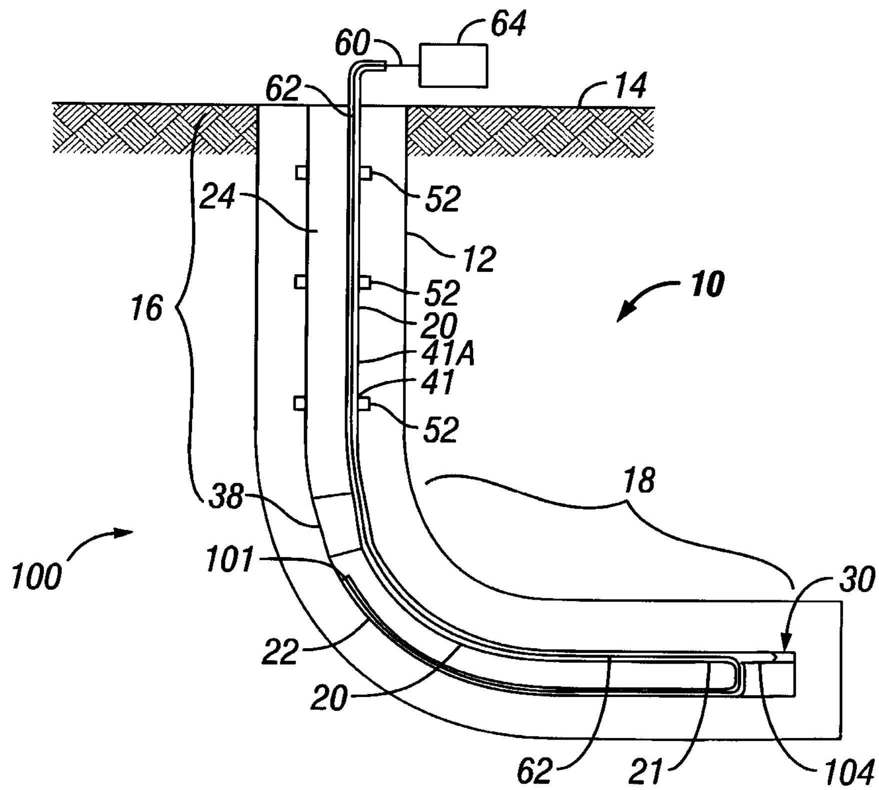

FIG. 9

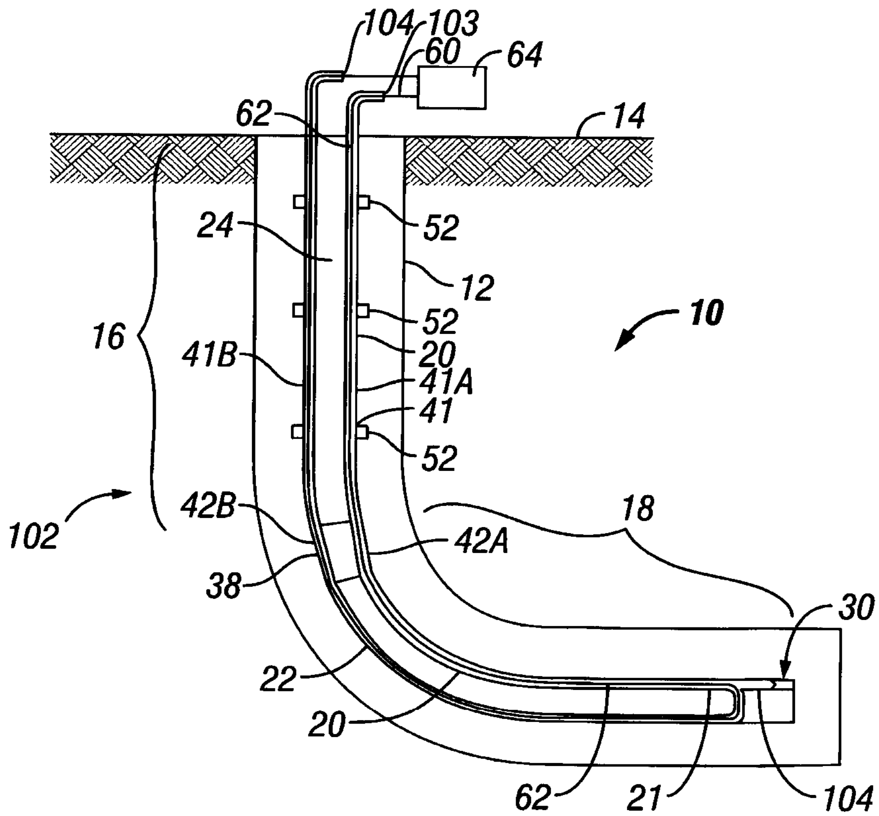

FIG. 10

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SYSTEM AND METHOD FOR RUNNING A CONTROL LINE

BACKGROUND

The invention generally relates to subterranean wells. More particularly, the invention relates to a deploying a control line in a subterranean well.

Control lines are often used in subterranean wells as conduits for fluids or for housing more sensitive components. For instance, control lines may contain a hydraulic fluid and may be connected to downhole devices such as packers or valves so that application of pressure on the hydraulic fluid activates the downhole devices. Instead of applied pressure, pressure signals communicated through the control line may also be used to activate the downhole devices. Control lines may also be used to inject chemicals into the wellbore at various stages during the life of the wellbore. In addition, control lines may house sensitive components, such as optical fibers and distributed temperature sensors, protecting such components from the harsh wellbore environment.

In the prior art, control lines are typically deployed outside of a conveyance device, such as a tubing or coiled tubing. To maintain the control line in place, clamps are used to attach the control line to the exterior of the conveyance device. Clamps, however, have various disadvantages. First, clamps are expensive. The attachment of clamps also takes time thereby delaying the deployment of the overall completion into the wellbore. And, the presence of clamps on the exterior of the conveyance device increases the friction of the conveyance device thereby increasing the possibility that the conveyance device will become stuck as it is deployed in the wellbore, specially if the wellbore is horizontal or highly deviated. The prior art would

benefit from a system and method for running a control line that minimizes the number of clamps used in the completion.

Thus, there exists a continuing need for an arrangement and/or technique that addresses one or more of the problems that are stated above.

SUMMARY

According to a first aspect, the present invention provides a method for running a control line in a subterranean wellbore, comprising: deploying a lower string into the wellbore; deploying an upper string into the wellbore; connecting the upper string to the lower string; and deploying a control line into the wellbore so that it extends within the lower string and outside of the upper string.

The invention further provides anchoring the control line within the lower string.

The invention further provides guiding the control line within the lower string.

The invention further provides that the anchoring step can comprise latching a lead end of the control line within the lower string proximate a bottom end of the lower string.

The invention further provides that deploying a lower string step can occur prior to the deploying a control line step.

The invention further provides that the deploying a control line step can comprise: deploying a bottom control line so that it extends within the lower string; deploying a top control line so that it extends outside the upper string; and providing fluid communication between the bottom control line and the top control line.

The invention further provides passing one of the bottom control line and the top control line through a port extending between an interior and an exterior of a ported sub; and connecting the bottom control line to the top control line.

The invention further provides connecting the bottom control line to an interior orifice of a port extending through a ported sub and connecting the top control line to an exterior orifice of the port.

The invention further provides cutting the bottom control line prior to the providing step.

The invention further provides clamping the control line outside the upper string.

The invention further provides transmitting a signal through the control line to operate at least one downhole device.

The invention further provides that the transmitting step comprises transmitting one of a hydraulic signal, an electrical signal, or an optical signal.

The invention further provides deploying a cable within the control line.

The invention further provides that the deploying step can comprise pumping the cable through the control line by use of fluid drag.

The invention further provides measuring a temperature profile along the control line.

The invention further provides that the measuring step can comprise deploying a sensing optical fiber in the control line and attaching the optical fiber to an interrogation unit.

The invention further provides providing the control line with a J-configuration.

The invention further provides providing the control line with a double-ended configutation.

According to a second aspect, the present invention provides a method for running a control line in a subterranean wellbore, comprising: (a) deploying a lower string in the wellbore; (b) after step (a), deploying a bottom control line in the lower string; (c) cutting the bottom control line; (d) after step (b), attaching a ported sub to the lower string; (e) after step (d), connecting the bottom control line through a port in the ported sub to a top control line; (f) after

step (d), attaching an upper string to the ported sub; and (g) clamping the top control line to an exterior of the upper string.

According to a third aspect, the present invention provides a system used to run a control line in a subterranean wellbore, comprising: a lower string adapted to be deployed in the wellbore; an upper string connected to the lower string; and a control line that extends within the lower string and outside of the upper string.

The invention further provides that the control line can be anchored within the lower string.

The invention further provides a latch mechanism adapted to latch the control line within the lower string.

The invention further provides that the latch mechanism can be located within the lower string proximate a bottom end of the lower string.

The invention further provides a guide for directing the control line to the latch mechanism.

The invention further provides a one-way valve in hydraulic communication with the control line.

The invention further provides that the control line can be in communication with at least one downhole device.

The invention further provides that the control line can be adapted to carry a signal to the at least one downhole device; and that the signal can comprise one of a hydraulic signal, an electrical signal, or an optical signal.

The invention further provides that the lower string can be deployed in the wellbore prior to the deployment of the control line.

The invention further provides that the control line can comprise a top control line and a bottom control line; the bottom control line can extend within the lower string; the top control line can extend outside the upper string; and the bottom control line can be in communication with the top control line.

The invention further provides that a ported sub can be attached between the lower string and the upper string; the ported sub can include a port extending between an interior and an exterior of the ported sub; one of the bottom control line and the top control line can pass through the port; and the bottom control line can be connected to the top control line.

The invention further provides that a ported sub can be attached between the lower string and the upper string; the ported sub can include a port extending between an interior and an exterior of the ported sub; the bottom control line can be connected to an interior orifice of the port extending; and the top control line can be connected to an exterior orifice of the port.

The invention further provides that the bottom control line can be cut prior to providing it with communication with the top control line.

The invention further provides that the control line can be clamped to an outside of the upper string.

The invention further provides that the cable can be housed within the control line.

The invention further provides that the cable can be pumped through the control line by use of fluid drag.

The invention further provides that a sensing optical fiber can be deployed in the control line, the sensing optical fiber measuring a temperature profile along the control line.

The invention further provides that the control line can have a J-configuration.

The invention further provides that the control line can have a double-ended

configutation.

Advantages and other features of the invention will become apparent from the following description, drawing and claims.

BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a schematic of the present invention wherein a control line extends outside of an upper string and inside a lower string.

Fig. 2 is a schematic showing the deployment of the lower string and bottom control line.

Fig. 3 is a schematic showing one embodiment of the latch mechanism.

Fig. 4 is a schematic showing another embodiment of the latch mechanism.

Fig. 5 is a schematic showing another embodiment of the latch mechanism.

Fig. 6 shows the bottom control line cut and the ported sub attached to the lower string.

Fig. 7 shows the control line extending through the port of the ported sub and the bottom control line connected to the top control line.

Fig. 8 shows the top control line attached to the upper string with clamps.

Fig. 9 is a schematic showing the control line in the J-configuration.

Fig. 10 is a schematic showing the control line in the double-ended configuration.

DETAILED DESCRIPTION

Figure 1 shows the completion 10 which is the subject of this invention. Completion 10 is deployed in a wellbore 12 that may or may not be cased. The wellbore 12 extends from a surface 14 into the earth. Completion 10 includes an upper string 16 and a lower string 18. Generally, control line 20 extends along the exterior of upper string 16 and along the interior of lower string 18. Control line 20 may comprise a bottom control line 21 and a top control line 41.

Lower string 18 may be a stinger and may comprise tubing 22, such as production tubing or coiled tubing. Upper string 16 may also comprise tubing 24, such as production tubing or coiled tubing.

Figure 2 shows the first step in the deployment of completion 10. Initially, the lower string 18 is deployed in the wellbore 12. This deployment is stopped when the top 19 of the lower string 18 is proximate the surface 14.

Next, as also shown in Figure 3, bottom control line 21 is deployed inside the lower string 18 by spooling or a suitable winding device. Bottom control line 21 becomes anchored to the lower string 18 once it is satisfactorily in place. In one embodiment, the lead end 28 of the bottom control line 21 is configured so that it latches to latch mechanism 30 located proximate the bottom 32 of the lower string 18. Thus, once latched into the latch mechanism 30, the bottom control line 21 securely extends within the interior of the lower string 18. Latch mechanism 30 may comprise an anchor, a conventional slickline nipple and lock system, or a wireline latch system.

In one embodiment, the lower string 18 may include a guide 34 proximate the lower string bottom 32 that directs the lead end 28 of the bottom control line 21 into engagement with the latch mechanism 30.

In another embodiment, instead of deploying the bottom control line 21 into an already deployed lower string 18, the lower string 18 is deployed with bottom control line 21 already in place.

A one-way valve 36 may also be functionally associated with the control line 20. Although the Figures (see Figure 4) show one way valve 36 located at the lower end of bottom control line 21 and as part of the latch mechanism 30, one way valve 36 may be located

anywhere along the length of control line 20. In one embodiment, one-way valve 36 comprises a ball 70 that is sealingly engaged against an orifice 72 by a spring 74 when no pressure is applied to the top of the ball 70. The spring 74 and ball 70, however, are rated so that when sufficient fluid pressure is applied to the top of ball 70, the spring 74 is compressed and the ball is dislodged from the orifice 72 thereby allowing the fluid to pass through the orifice 72 and out of the valve 36. Thus, if control line 20 includes hydraulic fluid that must be flushed out during an operation or at different times during the life of a well, valve 36 enables such hydraulic fluid to be released from control line 20.

In another embodiment as shown in Figure 5, control line 20 may also be in communication with at least one downhole device 31 so that the control line 20 may be used to activate the downhole device 31. In one embodiment as show in Figure 5, the communication with the downhole device 31 may be through latch mechanism 30. Activation may occur by applied pressure or pressure signals through the control line 20, or it may occur by electrical or optical signals that are sent through an appropriate cable inside the control line and though the control line 20. The donwhole device 31 may comprise any of a number of downhole devices, including valves, packers, perforating guns, chokes, pumps, etc.

In the next step shown in Figure 6, the bottom control line 21 is cut proximate the tubing head or surface 14 and a ported sub 38 is attached to the top 40 of the lower string 18. Ported sub 38 includes a port 42 that extends from the interior to the exterior of the ported sub 38.

Next, the top control line 41 is connected to the cut end 44 of the bottom control line 21 and the integrated control line 20 passes through the port 42 so that control line 20 extends within the lower string 18 below the ported sub 38 and outside of the ported sub 38 above the ported sub 38. In one embodiment (as shown in Figure 7), the cut end 44 of the bottom control

line 21 is routed through the port 42 so that the cut end 44 is connected to the top control line 41 outside of the ported sub 38. In another embodiment (not shown), the cut end 44 of the bottom control line 21 remains within the ported sub 38 and the top control line 41 is routed through port 42 so that the bottom control line 21 and the top control line 41 are connected within the ported sub 38. In yet another embodiment (not shown), the bottom control line 21 is sealingly attached to the interior orifice 46 of port 42 and the top control line 41 is sealingly attached to the exterior orifice 48 of port 42.

In those embodiment in which the top control line 41 is connected directly to the bottom control line 21, such connection may be implemented by a hydraulic connector 50, as such hydraulic connectors 50 are known in the art.

In the next step as shown in Figure 8, the upper string 16 is attached to the ported sub 38 and the top control line 41 is connected to the exterior of the upper string 16 by way of clamps 52 placed intermittently along the length of the exterior of the upper string 16. Deployment of the upper string 16 with the control line 20 attached to its exterior occurs during this operation.

Once fully installed, completion 10 includes a control line 20 that extends within the lower string 18 and outside of the upper string 16. Ported sub 38 enables the crossover of the control line 20 from the interior to the exterior of the completion 10. The control line 20 is securely in place and anchored within the lower string 18 (such as with latch mechanism 30), and, as previously discussed, may also have other functions.

Extending the control line 20 within the lower string 18 allows an operator to reduce the number of clamps used (in comparison to having to clamp the control line to the exterior of both the upper and lower strings) thereby also reducing the cost of the completion. Further, not having clamps on the exterior of the lower string reduces the friction of the completion as it is

deployed in the wellbore. This is specially true and important when the lower string extends into or through a bend or a horizontal section in the wellbore. Moreover, locating the control line at least partially within the completion (in the lower string) offers the control line and any components housed therein better protection against the harsh wellbore environment than locating the control on the exterior of the completion. In addition, deploying the bottom control line without having to clamp it at a plurality of location along its length also reduces the amount of time it takes to deploy the overall completion. Finally, by eliminating the clamps in the lower string 18, the overall outside diameter of the lower string 18 is reduced, thereby enabling the installation of downhole systems in the wellbore that were previously not able to be installed due to size constraints.

In one embodiment of the invention, an operator may elect to deploy a fluid within the control line 20. As previously disclosed, the fluid may be used to activate downhole devices 31. In another embodiment, the fluid may comprise a chemical which may be released through the one way valve 36 at relevant times during the life of the well in order to cause a certain chemical reaction. In another embodiment, the fluid may be chosen in order to prolong the life of a cable 60 (as described below) housed in the control line 20.

In an alternative embodiment, an operator may deploy and pressurize fluid in the control line 20 in order to set an anchor (not shown) which anchors bottom control line 21 within lower string 18. This embodiment would be as an alternative to or used in conjunction with latch mechanism 30.

In another embodiment as shown in Figure 1, an operator may deploy a cable 60 within the control line 20. The cable 60 may comprise an optical fiber 62. The optical fiber 62 may be used together with an interrogation unit 64 that may be located at the surface 14 to provide a

distributed temperature profile along the length of the optical fiber 62. Interrogation unit 64 may include a processor and a light source. In some embodiments of the invention, the temperature measurement system uses an optical time domain reflectometry (OTDR) technique to measure a temperature distribution along a region (the entire length, for example) of the optical fiber 62. Thus, the temperature measurement system is capable of providing a spatial distribution of thousands of temperatures measured in a region of the well along which the optical fiber 62 extends.

More specifically, pursuant to the OTDR technique, temperature measurements may be made by introducing optical energy into the optical fiber by the interrogation unit 64 at the surface of the well. The optical energy that is introduced into the optical fiber 62 produces backscattered light. The phrase "backscattered light" refers to the optical energy that returns at various points along the optical fiber 62 back to the interrogation unit 64 at the surface of the well. More specifically, in accordance with OTDR, a pulse of optical energy typically is introduced to the optical fiber 62 at the well surface 14, and the resultant backscattered optical energy that returns from the fiber 62 to the surface 14 is observed as a function of time. The time at which the backscattered light propagates from the various points along the fiber 62 to the surface 14 is proportional to the distance along the fiber 62 from which the backscattered light is received.

In a uniform optical fiber 62, the intensity of the backscattered light as observed from the surface 14 of the well exhibits an exponential decay with time. Therefore, knowing the speed of light in the fiber 62 yields the distances that the light has traveled along the fiber 62. Variations in the temperature show up as variations from a perfect exponential decay of intensity with distance. Thus, these variations are used to derive the distribution of temperature along the

optical fiber 62.

In the frequency domain, the backscattered light includes the Rayleigh spectrum, the Brillouin spectrum and the Raman spectrum. The Raman spectrum is the most temperature sensitive with the intensity of the spectrum varying with temperature, although all three spectrums of the backscattered light contain temperature information. The Raman spectrum typically is observed to obtain a temperature distribution from the backscattered light.

In summary, the processor may control the light source so that the light source emits pulses of light at a predefined wavelength (a Stokes wavelength, for example) into the optical fiber 62. In response to the pulses of light, backscattered light is produced by the optical fiber 62, and this backscattered light returns to the interrogation unit 64. The interrogation unit 64, in turn, measures the intensity of the resultant backscattered light at the predefined wavelength. Using OTDR techniques, the processor processes the intensities that are detected by the interrogation unit 64 to calculate the temperature distribution along some portion (the entire length, for example) of the optical fiber 62.

This distributed temperature profile enables the operator to have a profile of the temperature along the length of the wellbore 12. As known in the art, this temperature profile may be used to determine, among other things, the flow characteristics of the wellbore, including flow, the location of formations, or whether such formations are producing or not.

In another embodiment of the invention, the cable 60 comprises an electrical conductor. In this embodiment, the electrical conductor 60 may be used to electrically activate downhole devices 31 or it may be used to transmit information between the surface and the downhole environment.

In one embodiment, the cable 60 may be deployed within control line 20, including

through the port 42, by being pumped through control line 20. This technique is described in United States Reissue Patent 37,283. Essentially, the cable 60 is dragged along the control line 20 by the injection of a fluid at the surface. The fluid and induced injection pressure work to drag the cable 60 along the control line 20. This pumping technique is specially useful in the embodiment including one-way valve 36, since the pumping fluid may continuously escape via the one-way valve 36. This fluid drag pumping technique may also be used to remove the cable 60 from the control line 20 (such as if cable 60 fails) and then to replace it with a new, properly-functioning cable 60. In this replacement scenario, the one-way valve 36 is also configured to enable the release of the cable 60 therethrough.

In another embodiment, the cable 60 is already housed in the control line 20 during the deployment of the bottom and top control lines 21, 41. This embodiment may require the cutting and splicing of the cable 60 in conjunction with the steps shown in Figures 6 and 7.

Although the control line 20 has been described and illustrated in a single-ended configuration (wherein the control line terminates at the downhole location), completion 10 may include a control line 20 that has a J-configuration 100 (as shown in Figure 9) or a double-ended configuration 102 (as shown in Figure 10). The top 101 of the J-configuration 100 may be located at any location along the completion 10. In the double-ended configuration 102, both ends 103 and 104 of the control line 20 extend to the surface 14. In the embodiment in which an optical fiber 62 is housed within a control line 20 that has a double-ended configuration 102, both ends of the optical fiber 62 can be connected to the interrogation unit 64, providing greater resolution to the temperature measurement than in the single-ended configuration of control line 20. In both the J-configuration 100 and the double-ended configuration 102, the control line 20 may include an extension 104 which latches to latch mechanism 30 as previously disclosed.

In either the J-configuration 100 or the double-ended configuration, it is understood that completion 10 may require a ported sub 38 with two ports 42A and 42B. Moreover, the bottom control line 21 in these configurations would comprise a J-shaped or U-shaped section of control line 20. And, the top control line 31 in these configurations would comprise one (in some cases of the J-configuration 100) or two sections of top control line 41A and 41B (in some cases of the J-configuration 100 and in all cases of the double-ended configuration 102). It is understood that the steps described in relation to the single-ended configuration necessary to connect the bottom and top control lines may thus need to be duplicated for the two sections of top control line 41A and 41B.

While the invention has been disclosed with respect to a limited number of embodiments, those skilled in the art, having the benefit of this disclosure, will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of the invention.

CLAIMS

We claim:

1. A method for running a control line in a subterranean wellbore, comprising:

deploying a lower string into the wellbore;

deploying an upper string into the wellbore;

connecting the upper string to the lower string; and

deploying a control line into the wellbore so that it extends within the lower string and outside of the upper string.

2. The method of claim 1, further comprising anchoring the control line within the lower string.

3. The method of claim 2, further comprising guiding the control line within the lower string.

4. The method of claim 2, wherein the anchoring step comprises latching a lead end of the control line within the lower string proximate a bottom end of the lower string.

5. The method of claim 1, wherein the deploying a lower string step occurs prior to the deploying a control line step.

6. The method of claim 5, wherein the deploying a control line step comprises:

deploying a bottom control line so that it extends within the lower string;

deploying a top control line so that it extends outside the upper string; and

providing fluid communication between the bottom control line and the top control line.

7. The method of claim 6, further comprising:

passing one of the bottom control line and the top control line through a port extending between an interior and an exterior of a ported sub; and

connecting the bottom control line to the top control line.

8. The method of claim 6, further comprising connecting the bottom control line to an interior orifice of a port extending through a ported sub and connecting the top control line to an exterior orifice of the port.

9. The method of claim 6, further comprising cutting the bottom control line prior to the providing step.

10. The method of claim 1, further comprising clamping the control line outside the upper string.

11. The method of claim 1, further comprising transmitting a signal through the control line to operate at least one downhole device.

12. The method of claim 1, wherein the transmitting step comprises transmitting one of a

hydraulic signal, an electrical signal, or an optical signal.

13. The method of claim 1, further comprising deploying a cable within the control line.

14. The method of claim 13, wherein the deploying step comprises pumping the cable through the control line by use of fluid drag.

15. The method of claim 1, further comprising measuring a temperature profile along the control line.

16. The method of claim 15, wherein the measuring step comprises deploying a sensing optical fiber in the control line and attaching the optical fiber to an interrogation unit.

17. The method of claim 1, further comprising providing the control line with a J-configuration.

18. The method of claim 1, further comprising providing the control line with a double-ended configutation.

19. A method for running a control line in a subterranean wellbore, comprising:

(a) deploying a lower string in the wellbore;

(b) after step (a), deploying a bottom control line in the lower string;

(c) cutting the bottom control line;

(d) after step (b), attaching a ported sub to the lower string;

(e) after step (d), connecting the bottom control line through a port in the ported sub to a top control line;

(f) after step (d), attaching an upper string to the ported sub; and

(g) clamping the top control line to an exterior of the upper string.

20. A system used to run a control line in a subterranean wellbore, comprising:

a lower string adapted to be deployed in the wellbore;

an upper string connected to the lower string; and

a control line that extends within the lower string and outside of the upper string.

21. The system of claim 20, wherein the control line is anchored within the lower string.

22. The system of claim 21, further comprising a latch mechanism adapted to latch the control line within the lower string.

23. The system of claim 22, wherein the latch mechanism is located within the lower string proximate a bottom end of the lower string.

24. The system of claim 22, further comprising a guide for directing the control line to the latch mechanism.

25. The system of claim 20, further comprising a one-way valve in hydraulic communication

with the control line.

26. The system of claim 20, wherein the control line is in communication with at least one downhole device.

27. The system of claim 26, wherein:

the control line is adapted to carry a signal to the at least one downhole device; and

the signal comprises one of a hydraulic signal, an electrical signal, or an optical signal.

28. The system of claim 20, wherein the lower string is deployed in the wellbore prior to the deployment of the control line.

29. The system of claim 28, wherein:

the control line comprises a top control line and a bottom control line;

the bottom control line extends within the lower string;

the top control line extends outside the upper string; and

the bottom control line is in communication with the top control line.

30. The system of claim 29, wherein:

a ported sub is attached between the lower string and the upper string;

the ported sub includes a port extending between an interior and an exterior of the ported sub;

one of the bottom control line and the top control line pass through the port; and

the bottom control line is connected to the top control line.

31. The system of claim 29, wherein:

a ported sub is attached between the lower string and the upper string;

the ported sub includes a port extending between an interior and an exterior of the ported sub;

the bottom control line is connected to an interior orifice of the port extending; and

the top control line is connected to an exterior orifice of the port.

32. The system of claim 29, wherein the bottom control line is cut prior to providing it with communication with the top control line.

33. The system of claim 20, wherein the control line is clamped to an outside of the upper string.

34. The system of claim 20, wherein a cable is housed within the control line.

35. The system of claim 34, wherein the cable is pumped through the control line by use of fluid drag.

36. The system of claim 20, wherein a sensing optical fiber is deployed in the control line, the sensing optical fiber measuring a temperature profile along the control line.

37. The system of claim 20, wherein the control line has a J-configuration.

38. The system of claim 20, wherein the control line has a double-ended configutation.

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Application No: GB 0304477.3
Claims searched: 1-38

Examiner: Alan Jones
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Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1, 2, 11-13, 17, 20, 21, 26, 27, 34, 37	US 6302216 B1	(PATEL) see eg. fig 1, control line 52
X	1, 2, 11-13, 20, 21, 26, 27, 34	US 5141057 A	(CHAIX) see eg. figs 7-10
X	1, 2, 4, 10-13, 20, 21, 26, 34	US 4062551 A	(BASE) see eg. abstract and fig 1
A		US 6302203 B	(JOHNSON ET AL) see eg. fig 2d

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{V}:

E1F

Worldwide search of patent documents classified in the following areas of the IPC^{7} :

E21B

The following online and other databases have been used in the preparation of this search report :

Online: WPI, EPODOC, JAPIO